FOR DISCUSSION

ONTARIO MINISTRY OF SKILLS DEVELOPMENT

TRAINING FOR TECHNOLOGICAL CHANGE:

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The Role of Skills Training in the Process of Technology Diffusion in Ontario

Fall, 1987

Ministry of Skills Development
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NOTE: This discussion paper is available in French.

INTRODUCTION

This report has been prepared to review the role that skills training can play in the process of technological innovation in the Ontario economy.

Each new wave of innovation has introduced new skills to the labour force and posed new training requirements. With another wave of widespread industrial change, this one involving so-called "information" technologies (a synthesis of computing, electronics and communications), these issues are raised anew.

In conceptual terms, the availability, flexibility and quality of skilled personnel can play a very significant role in determining the pace and extent of diffusion of a technology (or cluster of technologies) in a given economy.

In practical terms, however, new technologies normally have a series of marginal effects on an existing economic base. Equally, they will make marginal demands on the existing skill set of the labour force. In order to arrive at meaningful conclusions about the role that skills training can play in the technology diffusion process, it is, therefore, essential to seek answers to some very specific questions. In particular, the following issues need to be addressed:

- What are the new technologies that are likely to have an impact on the Ontario economy over the next decade?

- Do these new technologies necessitate radically new skills by workers and management or simply a refining of existing skill sets?

- Will firms be able to meet their new skill needs through retraining of existing personnel or will they have to hire replacements? Are these replacements available and at what price?

- Do perceived or anticipated skill scarcities inhibit the pace at which a firm will adopt a new technology?

- Do certain new technologies pose risks of generic and widespread skills bottlenecks with the potential for breakdowns in training systems?

- Can training anticipate technological development? If so, should skills training be used as a strategic weapon to train in anticipation of technological innovations in order to accelerate the diffusion process?

- What kinds of training programs are needed to facilitate technology diffusion? Among workers? Among management?

This paper is set out in six parts. The first section describes the technology challenge facing Ontario, and surveys the factors that can facilitate and impede the process of technology diffusion. A number of models of the diffusion process are examined in order to identify the role that skills quality and flexibility can play in the process.

The second section surveys the emerging technologies that are expected to shape Ontario's economy over the next five to ten years and reviews the implications for skill requirements that are likely to result from the application of certain key technologies. Particular emphasis is directed to certain advanced manufacturing process technologies, and organizational technologies such as statistical process control and just-in-time production, that are expected to have widespread application over the next decade.

The third section draws on recent studies of how manufacturing and service sector firms have coped with skills changes brought about by technical change. Most of the studies summarized are Canadian. However, some European and U.S. studies are cited to explore whether Canadian experience is consistent with that in other industrialized countries. This section concludes by highlighting certain broad themes that can be drawn from the industry surveys.

The fourth section briefly reviews the training programs that are available in Ontario to assist workers, managers and firms adjust to technological change.

The fifth section spells out the implications of technology diffusion for skills training in the future and identifies developments that may place new demands on the training system in Ontario.

The final section draws conclusions and presents recommendations for action.

THE PROCESS OF TECHNOLOGY DIFFUSION

THE TECHNOLOGY CHALLENGE

The introduction of technology serves two economic purposes. First, it improves efficiency in the production of existing products and services. Second, it leads to the introduction of new products and services that fill new needs.

Clearly, innovation is one of the driving forces, if not the prime mover in economic progress. As innovations diffuse through the economy, they help to enhance product quality, reduce costs and improve productivity. In short, they contribute to improved competitiveness and enhanced living standards in a given economy.

For an individual firm, the successful early adoption of an innovation puts it ahead of its competitors and in a position to earn better profits and to develop or increase exports.

For the economy as a whole, especially for a small, high-wage, export dependent economy such as Canada's, there are equally clear benefits of being near the leading edge of technology adoption. The payoff lies in improved productivity which sustains high incomes, and in the ability to compete internationally even with short production runs.

Unfortunately, Canada's innovation record does not match those of other industrial countries. For example, as illustrated by Figure 1, Canada ranks poorly among OECD countries on a number of measures of R&D performance. This poor innovation performance reflects a number of factors. Part of the explanation lies with the relative lack of defence-related research and development that takes place in Canada. Market size, foreign ownership and the greater role of the resource sectors in the Canadian economy (which tend to be less R&D intensive than manufacturing) are also significant reasons.

However, perhaps of more concern is the relatively slow pace of adoption, by Canadian industries, of existing commercialized technologies. While original research in bio-engineering or fifth generation microtechnology will command the spotlight in the next decade, the important economic success stories should be those that involve the use of Canadian skills to develop creative new adaptations and extensions of existing technologies. Some new industries will be created, but the biggest impact will be from the use of new technologies to revitalize old industries, whether it be in forestry, fishing, mining, manufacturing or services. However, as with innovation, the technology diffusion process in Canada has historically lagged that of Japan, the U.S., and Western Europe.

The Economic Council of Canada has found that the process of diffusion of technical change into and throughout Canada occurs more slowly than in other Western developed nations and this technology gap exists not only in the manufacturing sector but in the services sector as well.

Excessive lags in Canada's rate of technology adoption will mean that productivity gains are not captured quickly by existing industries, with adverse consequences for their international competitiveness. The European Management Forum notes that Canadian productivity levels are already 40% lower than in the U.S.; 25% lower than West Germany and 15% lower than Japan.

FIGURE 1

INTERNATIONAL COMPARISON
OF RESEARCH INTENSITY
1971, 1977, AND 1981

	1971		1977		1981	
	GERD/GDP* (per cent)	Rank	GERD/GDP (per cent)	Rank	GERD/GDP (per cent)	Rank
United States	2.68	1	2.39	1	2.54	1
Switzerland	2.33	2	2.29	2	2.40	3
West Germany	2.19	3	2.14	3	2.40	3
Netherlands	2.17	4	1.99	4	1.90	5
France	1.91	5	1.76	7	1.97	4
United Kingdom	1.90	6			2.43	2
Japan	1.83	7	1.91	5	2.40	3
Sweden	1.48	8	1.87	6	1.88	6
Belgium	1.40	9	1.40	9	1.36	7
Canada	1.35	10	1.07	10	1.25	9
Norway	1.10	11	1.41	8	1.28	8

*Ratio of gross expenditure on research and development (GERD) to gross domestic product (GDP).

SOURCE: Science Statistics Centre, Statistics Canada.

This situation could deteriorate. According to the Ontario Centre for Advanced Manufacturing (OCAM), Ontario is lagging behind other manufacturing nations in the rate of application and adoption of advanced automation technology. Moreover some developing nations, which already enjoy wage advantages, are applying these technologies at an increasing rate and possibly as fast as in Canada. If Ontario's poor record in adopting automated manufacturing technologies persists, this will translate not only into low relative productivity levels, but also higher unit costs, quality disadvantages and slower response to market changes.

OCAM notes that although 10,000 out of Ontario's 18,000 manufacturing firms could profitably avail themselves of some aspect of advanced manufacturing technology (computers, CAD/CAM, automation, robotics) the vast majority of Ontario firms are small and 70% of these have no engineers on staff to track and apply the new technologies.

Since substantial benefits could be realized if the diffusion process into and throughout Canada were to be speeded up, it is important to understand what factors facilitate and impede the process of technology diffusion and the role that skills training can play in that process.

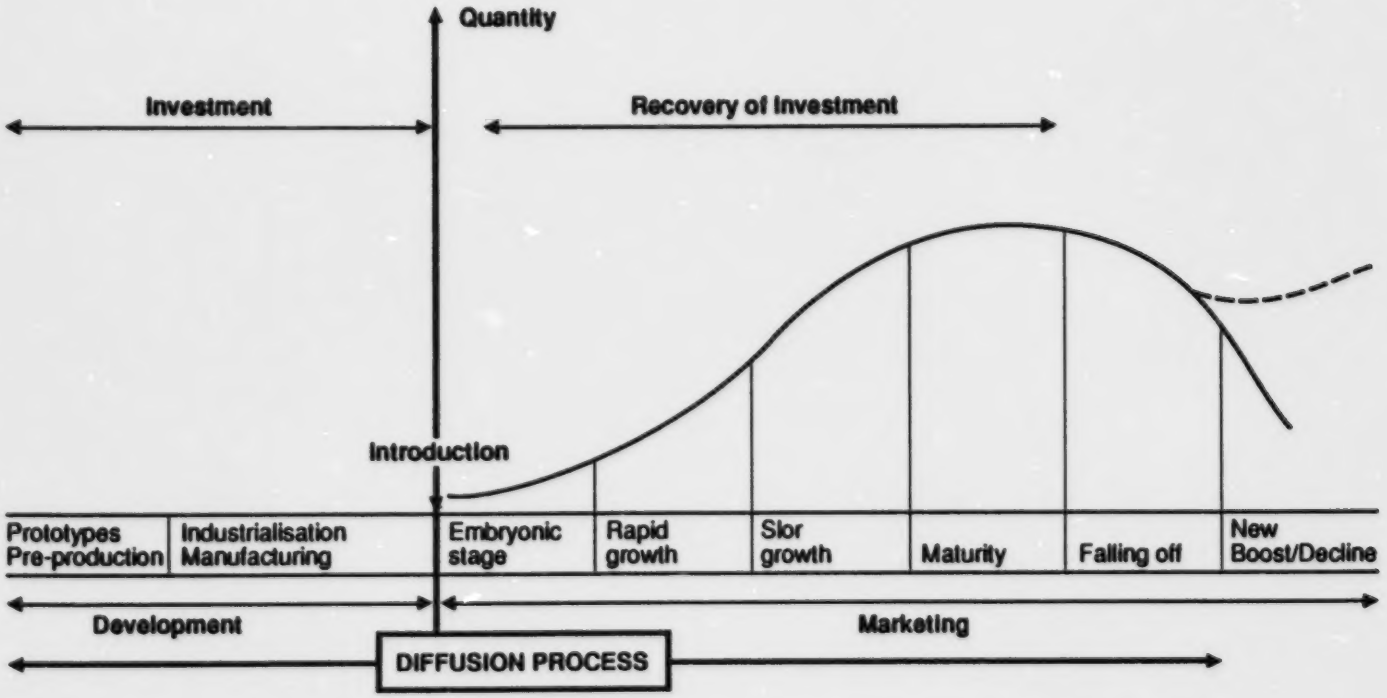
TECHNOLOGICAL CHANGE

An ongoing process of technological change has been the hallmark of Western industrial development since the start of the Industrial Revolution. Technological change is a process that spans both the creation and the adoption of new technology.

The overall process of technological change takes place in four phases -- invention, innovation, diffusion and decline. However, these usually overlap and influence each other: even as new products and processes are diffusing through an economy they will continue to be modified and improved. (Figure 2)

FIGURE 2

Diffusion Process and the Product Life Cycle



SOURCE: Adapted from: PIATIER, A.; Barriers to Innovation. Frances Pinter, 1984.

The rates at which any technology is likely to move through these phases is difficult to estimate. The adoption of new technologies is driven by judgements made by organizations and individual consumers as they take up newly created technology. Individual consumers make value judgements about the relative importance of new goods or services. Business and governments make judgements about the ability of new production techniques to supply existing or new products competitively. Collectively these judgements affect the rate of technological change in a given economy. (see Figure 3)

In general, there is a tendency to overestimate the speed at which a new technology is likely to be adopted in the short run. This in part reflects a serious underestimation of the barriers to commercial adoption and diffusion. On the other hand, there is also a tendency to underestimate the magnitude of the long run impacts of the changes that can be induced by the new technologies.

TYPES OF TECHNOLOGICAL INNOVATIONS

Technology is not just about machines: it is about the skills and knowledge and organization to put those machines to best use. Technology is more than knowing-about; it is know-why and know-how. Technology which is no longer being used soon becomes unusable because the necessary skills quickly become lost.

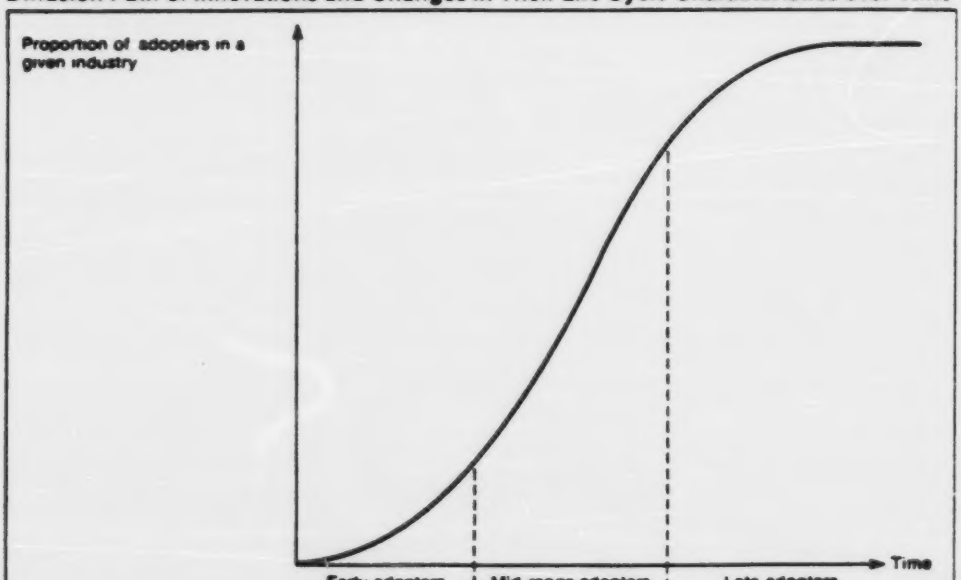
The report of the Canadian Automotive Industries Task Force notes that technological innovations can be categorized in one of three ways:

1) Product Innovations: Examples of recent product innovations would include computers, word processors, computerized numerically controlled equipment and new materials.

2) "Hard" Process Innovations: These could include the kinds of physical plant, machinery and equipment used in the production process such as programmable automation, robotics, and

FIGURE 3

Diffusion Path of Innovations and Changes in Their Life Cycle Characteristics over Time



Stages in innovation life cycle

Characteristic	Early stage	Growth	Maturity
Risk	High	Decreasing	Low
Price elasticity	Low	Increasing	High
Unit profit margins	High	Decreasing	Low
Competition	Based on product performance	Increasing standardization	Based on product differentiation and price
Production runs	Short	Lengthening	Mass production
Factors of production	High skilled-labour intensity; low capital intensity	Increasing capital intensity	Unskilled-labour intensity; high capital intensity
Export potential	High	Growing investment abroad	Increasing import competition

Source: Based on L. T. Wells, ed., *The Product Life Cycle and International Trade* (Cambridge, Mass.: Harvard University Press, 1972), pp. 3-33.

SOURCE: Economic Council of Canada; The Bottom Line. 1983.

computer assisted design. These require potentially large capital expenditures to implement. Some applications will require more skills; others will require fewer skills.

3) "Soft" Process Innovations: These are the technologies of production management, such as statistical process control (SPC), and just-in-time (JIT) production. These technologies are by definition about people; in particular about the way people and equipment are organized in relation to each other and to the tasks at hand. They place a premium on the intellectual and human skills required for team work and for assuming responsibility for more than a single isolated operation in the production process.

Therefore, although these do not require large capital expenditures, firms must make significant investments in time, training and commitment to implement them.

TECHNOLOGY DIFFUSION

Diffusion refers to the adoption of a new process or imitation of a new product after it has been successfully commercialized.

As Dungan and Younger point out, there are four levels of diffusion of technology:

- Diffusion takes place within a single firm, from, for example, a technically sophisticated production department to a less advanced sales or administration department;
- Diffusion occurs between firms in a given industry, where the hotly debated issue revolves around whether large or small firms innovate more rapidly;
- Technology diffuses between industries; and
- Diffusion takes place between countries, where technological leadership is often linked to superior competitiveness.

The focus of this discussion paper is diffusion between firms within a single industry and between firms in different industries in Ontario.

A key goal for a firm seeking to improve its competitiveness through innovation is the adoption of "best practice technology", i.e. the most modern and appropriate technology in use in a given industry.

Hcwever, this seldom means simply the purchase of new state-of-the-art machines. For the diffusion process to be judged successful, the innovation must be embodied in the operation of the adopting firm. It should be the outcome of a deliberate, and systematically organized act. The test of a successful diffusion process is not simply whether the firm is able to use the new technology but whether it has mastered it; that is, whether it can integrate it into its subsequent design, development, production and marketing processes.

THE PROCESS OF TECHNOLOGY DIFFUSION

The factors affecting the speed with which new technology diffuses are many and the relationships among them are complex. Nevertheless there seems to be widespread agreement that certain subsets of management and worker skills and the interaction between management and the workforce are central to the ease and pace with which a given technology will be adopted and the degree to which it will be successfully implemented.

A number of models have been developed to capture the process of technology diffusion. The following three models are useful in highlighting different aspects of a very complex process.

1) AN INPUT-OUTPUT MODEL: This approach demonstrates the central role played by the firm. The innovative firm is the nucleus of a range of key inputs (technical and market information, consulting advice, skilled

workers, financing, machinery, tooling, materials) which it transforms into new products, processes and services for a variety of potential domestic and foreign markets. (Figure 4)

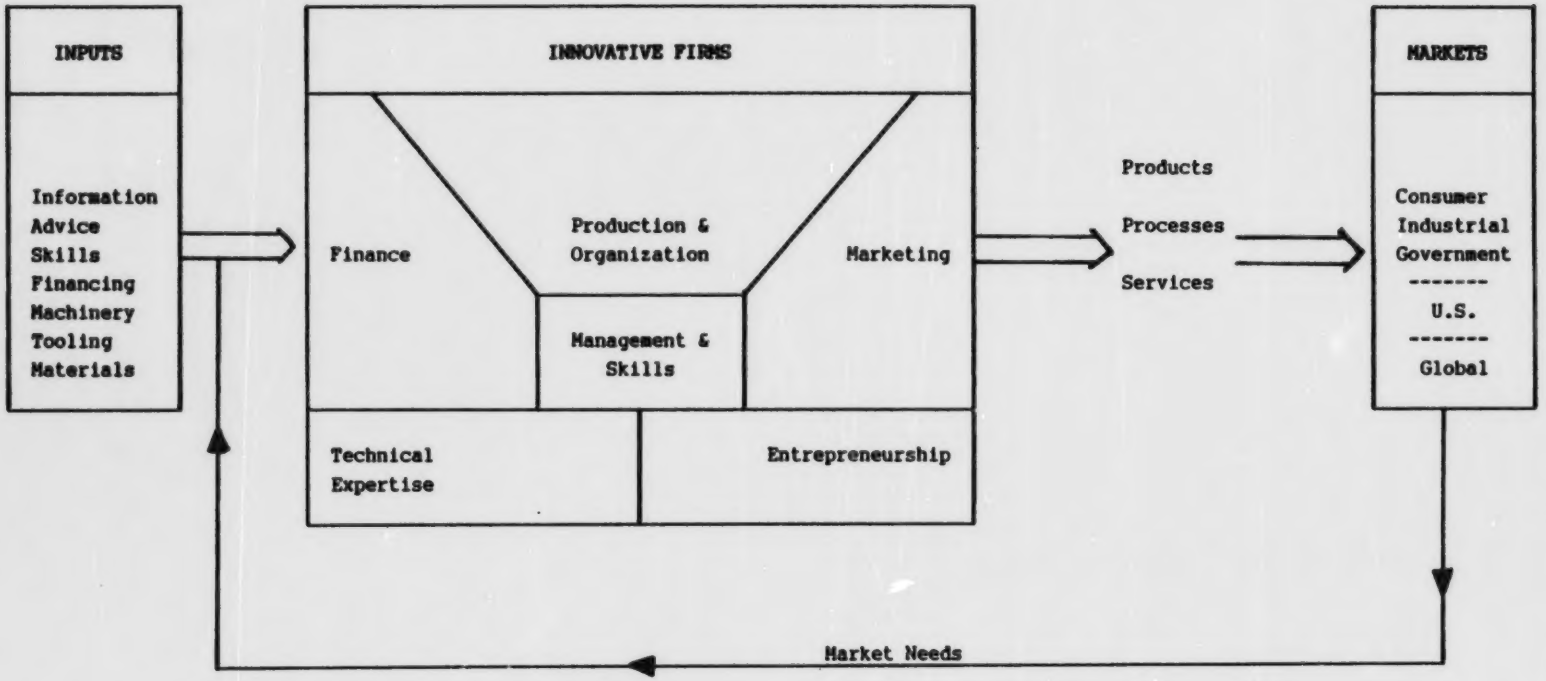
Characteristics such as firm size, ownership, innovative drive, and organizational effectiveness explain much about which firms will succeed more readily than others in adopting and implementing new technologies. So, too, do skill levels and the flexibility of the workforce.

Nevertheless, while the firm itself is the key point in the process, it is also clear that the successful diffusion of a technology is assisted by the quality and availability of the external inputs, including skilled people and training resources.

2) A MOTIVATIONAL MODEL: This model brings out not only the importance of motivation in the technology adoption process but also the fact that desire may not be enough to overcome barriers to innovation. In this model the technology adopter moves from broad awareness of the existence of a technology, to having an interest in its potential benefits, to having a desire to apply the technology, to committing resources to acquiring the technology. This model is also useful in bringing out the role that transfer mechanisms or agents can play in moving the firm from awareness to desire. (Figure 5)

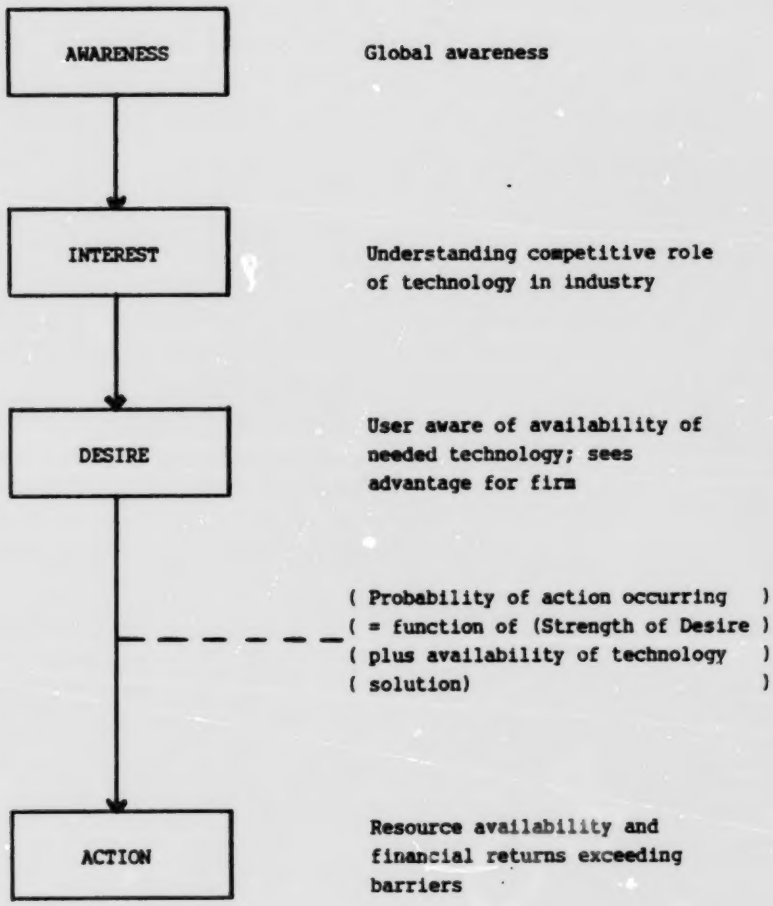
Case studies show that the existence of an "innovation champion" can often be vital to the process of technology diffusion within an organization. One role of the innovation champion is to persuade senior management of the need for a new technical process or system. Other roles may involve overseeing the evaluation, acquisition and successful installation of the innovation. To be effective, the drive and persuasiveness of the innovation champion needs to be backed up by sound technical judgement. As such, this role has increasingly become the province of the engineer or scientist.

FIGURE 4



SOURCE: HILL, Roger; Economics Consultant, Toronto, 1987.

FIGURE 5


AWARENESS
Global awareness
INTEREST
Understanding competitive role of technology in industry
DESIRE
User aware of availability of needed technology; sees advantage for firm
(Probability of action occurring)
(= function of (Strength of Desire)
(plus availability of technology)
(solution))
ACTION
Resource availability and financial returns exceeding barriers

SOURCE: LAPP, Philip; Technology Transfer in Ontario: Awareness and Program Mechanisms. Ontario Ministry of Industry, Trade and Technology, 1985.

In the final analysis, however, it is senior management that will make the innovative decisions. The skills which management brings to the decision-making process are clearly critical. They are also skills which can be taught, often by experience but ideally through training.

3) A LINEAR PRODUCTION MODEL: Whatever the initial impulse (technology push or demand pull), a successful process of technology diffusion in an individual firm is the outcome of a series of steps.

By viewing these as a linear process (adaptation, preproduction, production and marketing), it is easier to understand the time-lags, risks and role of facilitating agents. Each stage necessitates a unique set of diverse skills brought together in an ad hoc team. The innovation project leader, who may not necessarily also be the innovation champion, is often a key factor in the implementation of a new technology. This person usually has a strong technical background, such as engineering, but needs to possess or acquire interpersonal and managerial skills, to move the project from one phase to another. Training of project leaders in these practical and theoretical skills could be very instrumental in facilitating the innovation process.

Although conceptually useful, a linear presentation of the process does not adequately capture its reality, which is one of multiple innovations and feedback. An innovation will rarely be implemented in isolation of other changes. An innovation may require technological modifications to other inputs, new tooling, organizational changes, etc. The result will be new feedbacks upstream, further complications in an already complex process and more demands on the skills of the project team and project leaders.

BARRIERS TO DIFFUSION

The rate of diffusion is dependent on the potential adopters' appreciation of the advantages offered by the technology in their particular circumstances (which must outweigh perceived risks or fears) and on their understanding of the elements necessary for successful adoption (which must be followed up by organization and action).

In most firms, the decision to go ahead with a new technology is a management decision. So too are decisions on how the new technology will be implemented and how workers will be subsequently retrained (or laid off in favour of new recruits). However, much new technology is a black box. Other than in its most obvious applications it is often not readily evident what the full potential of the new technology will be. If management lacks the skill to understand the potential of the technology or to evaluate it in a dynamic rather than a static sense, the decision will be to hold back on the investment.

For example, two central considerations - risk and rate-of-return factors - are at the heart of most decisions to adopt a new technology. However, as Leonard-Barton and Kraus have argued, traditional financial models are often deficient in evaluating many of today's computerized technologies since they do not capture non-traditional benefits such as product quality improvements, impact on market share, or the benefits of the more flexible use of production or distribution facilities. Without these considerations the investment may be judged to be uneconomic. Financial models may have difficulty capturing the dynamic potential of a new technology, such as future cost avoidance and the benefits from increased information flows.

One important issue for public policy is the relationship between public and private benefits. Edwin Mansfield and others have shown that the private rates of return to the firm (even allowing for a full evaluation of the technology) are often significantly less than

the social rates of return from adopting a new technology. This implies that there is a compelling argument for government support, including training subsidies, to ensure that no significant underinvestment takes place in new technologies.

Skills shortages of engineers, technicians and technologists (both real and perceived) are often cited by management as a barrier to innovation. Conversely, the skill and flexibility of the existing workforce to put the new technology to full use (after appropriate training) and thereby capture the technology's full potential, should facilitate the innovation process.

It is clear that deficiencies in management skills - especially in the areas of technology awareness, technology evaluation, and technology implementation - together with shortages of technical skills and outmoded worker skills, can all act as critical constraints to the process of technological change in Ontario.

SKILLS IMPLICATIONS OF EMERGING TECHNOLOGIES

EMERGING TECHNOLOGIES

Emerging technologies are defined to include new or modified products, techniques and processes that are rapidly diffusing through the Canadian economy or can be expected to become widely commercially applicable over the next decade.

Although different approaches have been used in various studies to categorize the emerging technologies, there is a clear consensus that computer-based technologies will continue to have the dominant impact on the labour force over the next ten years, just as they have over the past ten years. At the heart of this computer revolution are innovations in microelectronic technology which have enabled tremendous computing power to be incorporated into relatively small devices at drastically reduced costs.

However, the leading edge of application of computer technology is shifting. During the last five years, the dominant application of computer technology was in low-cost office automation - word processing and personal computers. In the next five years, as indicated in the results of the Economic Council survey set out earlier, the trend in Canada is towards more process automation (especially computer-assisted manufacturing) and to the wider use of office networks. (Figure 6)

FIGURE 6

THE INTRODUCTION OF TECHNOLOGY

		Introduced 1980-85	Planned 1986-90
		(percentage of all applications)	
I.	**PROCESS AUTOMATION**	**22.9**	**33.5**
	Automated material handling systems	3.1	4.1
	Computer numerical control (CNC)	3.1	3.2
	Computer-assisted manufacturing (CAM)	9.2	14.3
	Computer-assisted design (CAD)	5.1	8.4
	Automated inspection and quality control	2.4	3.5
II.	**OFFICE AUTOMATION**	**64.0**	**50.6**
	Word processing	17.3	9.3
	Personal computers/workstations	25.3	15.4
	Office networks	4.5	9.9
	Office applications	16.9	16.0
III.	**OTHER AUTOMATION**	**13.2**	**16.0**
	Transportation, communications and other utilities-specific applications	1.7	1.5
	Health services-specific applications	2.0	3.0
	Point-of-sale (POS)	4.7	5.7
	Other applications	4.8	5.8
	TOTAL	**100.0**	**100.0**

SOURCE: BETCHERMAN, Gordon and Kathryn McMullen; Working with Technology: A Survey of Automation in Canada. Economic Council of Canada, 1986.

Computer-based technology will also make possible the more widespread application of certain "soft" or organizational technologies such as statistical process control and just-in-time production and delivery.

Although other groups of new technologies may become commercially applicable in the next ten years, they are unlikely to have as significant employment impacts.

For example, biotechnology is still at the research and development stage. The Science Council's survey of Canadian scientists and engineers in late 1984 indicates that they foresee the main focus of biotechnology to be on applications and adaptation of advances in recombinant DNA, membranes, cloning, cell and tissue culture, and instrumentation. Commercial applications will be concentrated initially in relatively few fields, such as pharmaceuticals, food and agriculture, and health and also in the relatively capital intensive areas of those industries.

New materials technologies, particularly in the area of high strength ceramics, have the technical promise for important commercial breakthroughs, but probably not so widespread that there will be a significant impact on employment over the next 5 to 10 years. The Science Council fears that the growth of advanced industrial materials poses threats, in the long term, for Canada's resource-based economy. These new technologies will substitute new materials for the traditional materials on which so much of the Canadian economy depends.

Canadian scientists and engineers also identify new instruments as forming an important cluster of emerging technologies. The other major cluster of new technologies is linked to energy developments. The prime constraints for the commercialization of these energy technologies is the relative costs of the new processes and products compared to the price of conventional crude oil and natural gas.

The following matrix (Figure 7), developed by the Science Council, identifies the potential sectors of impact of these emerging technology clusters.

FIGURE 7

EST Telephone Survey: Matrix of Emerging Technologies and Sectors of Impact

Sector of impact	Information technologies	Biotech-nologies	Advanced industrial materials	Energy technologies	Other technologies
Widespread societal impact	●	•	•	•	•
Agriculture	•	●	•	•	•
Forestry	•	•	•	•	•
Fisheries	•	•	•	•	•
Mining/energy	•	•	•	•	•
Manufacturing	●	•	•	•	•
Communication	•		•	•	•
Services	•	•	•	•	•
Utilities	•	•	•	•	•
Construction	•	•	•	•	•

SOURCE: STEED, Guy and Scott Tiffen; A National Consultation on Emerging Technology. Science Council of Canada, 1986.

SKILLS AND NEW TECHNOLOGIES

In order to evaluate more precisely the implications for skills training of the more widespread application of the technologies that are expected to begin rapid diffusion through the economy, this section reviews the skills issues that have arisen in the application of a number of process technologies (robotics, flexible manufacturing systems, computerized numerical machine tools, and computer-assisted design), and two organizational technologies (just-in-time delivery/production systems and statistical process control).

ADVANCED MANUFACTURING TECHNOLOGIES

Advanced manufacturing technologies (AMT) cover a very broad range of scientific and engineering disciplines that are combined to produce systems used in a wide variety of applications. The main areas currently covered by AMT are computer-aided design, computer-aided manufacturing, robotics, controlled machine tools and flexible manufacturing systems. The particular skill implications of some of these specific applications will be looked at in more detail in the remainder of this section.

The comments on AMT, contained in the 1984 DRIE study reviewing key technologies of importance to Canada, are instructive. The report notes that Canada is behind the U.S. and other industrialized countries in the application of most advanced manufacturing technologies. The gap on average varies from two to six years. If nothing is done, it will continue to widen.

A number of major problems were defined by DRIE:

- First, there is a general lack of awareness in the Canadian business community on the benefits offered by AMT. Even with the advent of CAD/CAM and other Technology

Centres, potential users do not know enough about the technologies to make choices.

- A second observation is that there is a lack of Canadian consulting firms with expertise in AMT applications.

- Another problem is that Canadian universities and colleges are not well equipped to train enough engineers and technicians specialized in AMT.

- Finally, senior management does not adequately support implementation of AMT due to lack of knowledge and its reluctance to change.

It is clear that improving management skills in the awareness, evaluation and implementation of new technologies must be a counterpoint at all times to considerations of upgrading workforce skills.

INDUSTRIAL ROBOTS

An industrial robot has been defined by the U.S. Robotic Industries Association as "a reprogrammable multifunctional manipulator designed to move objects through variable programmed motions for the performance of a variety of tasks."

In a review of the impact of industrial robots on employment and skills, Karl-H Ebel notes that while the rate of diffusion of robots is increasing, the pace is evolutionary not revolutionary. This reflects a number of factors:

- Although the price of robots is falling and they are getting more sophisticated, while the price of labour is rising, the economic justification for installing robots still tends to be weak. The payoff period ranges from two to seven years, whereas in general a payoff period of one and a half years or less for machinery is considered profitable.

- Industrial robots are primarily useful in mass production and are confined to specialized repetitive tasks. Their area of application is therefore limited.

- While the scope of robot applications is widening (third generation robots equipped with sensors, actuators and artificial intelligence are moving into assembly work) robotization in these cases often also involves the costs and time of redesigning components and products.

Ebel notes that a high degree of expertise in automation is required at all levels of an enterprise to make robotization a success. In the U.S. it has been estimated that 75% of automation projects do not perform to full capacity. There are usually major start-up and debugging problems. The running-in time for new robot installations and systems is between two and five years. These facts are leading to the recognition that robots will not work without people and skills.

To be successful, management needs to evaluate the investment costs not only in terms of the purchase price of the robots but also of factory adaptation costs, software requirements, accessory equipment and manpower training.

The experience of the Japanese and the Swedes, who lead in the number of robots per capita employed in manufacturing, is that the diffusion of robots was considerably helped by the availability of a labour force that through its education, skill level and versatility has adapted to the potential of robotization.

Industry regards the shortage of qualified staff as the most common obstacle to automation. Automation equipment is too expensive and vulnerable to be handled by underqualified staff. For example, robot maintenance requires workers with electrical, electronic, mechanical, hydraulic and programming skills. However, such training can be difficult and costly to provide and the firm always fears losing such skilled workers to their competitors.

In conclusion, Ebel observes that the effective and successful use of robots requires a long learning process in enterprises, a commitment of the workforce to technical change, and cooperation between management and the shop-floor. Worker skills and retraining are a central part of a successful process.

CNC MACHINE TOOLS

The use of numerical control (NC) and computerized numerical control (CNC) machine tools in Ontario was reviewed by the Ontario Ministry of Industry, Trade and Technology in 1985. In its examination of the obstacles to further diffusion, the study notes:

- A shortage of skilled operators and management deficiencies in system choice and planning were jointly cited as the most important obstacles, followed by financial constraints.

- The shortage of competent, trainable operators and programmers was often identified as the greatest bottleneck impeding NC/CNC use. Skills such as general machine knowledge, mathematical skills, the ability to visualize in several dimensions, and an understanding of the properties of metals and other materials were viewed as vital if the NC/CNC technology was to be fully exploited. Skilled workers minimized the high costs of downtime and captured fully the quality potential of the machinery. Electronics "mechanics" were considered essential for troubleshooting but were apparently in very short supply.

- As the equipment and technology continues to change, on-going training is required. In some cases, the MITT report states that management has shown reluctance to sending operators back to school or to the equipment supplier for training. This is not the case in the vehicle assembly industry, however. The Automotive Industries Task Force Report indicates that motor vehicle manufactures are engaged in massive training programs to

arm their electricians and machine repairers with the knowledge to operate, maintain and repair automated equipment. In some cases 2000 hours of retraining are required.

- Although for financial reasons equipment purchases tend to proceed sequentially, careful system planning is essential if the full productivity potential is to be realized. This necessitates management awareness and training to assess the full range of costs, benefits and risks among competing options. Production managers may lack understanding of automated systems, while systems specialists lack knowledge of the factory floor.

FLEXIBLE MANUFACTURING SYSTEMS

A flexible manufacturing system has been defined by the United Nations Economic Council for Europe as "a production system with the following characteristics:

- An automated production system for the manufacture of a large variety of workpieces in small batches with minimal setup times;

- A machine system consisting of a number of NC machines ... robots and ... workstations tied together with an automated workpiece and tool handling system. This latter is the sine qua non of FMS;

- A system in which all major functions are controlled by one or more computers which download NC programs to individual machines and robots, control workpiece flow, and generate performance reports; and

- A system in which the following functions are carried out automatically through software: production scheduling, part-program selection, cutting-abnormality detection, tool breakage detection, tool wear compensation, pallet retraction, automatic measuring, and certain self-diagnostic functions."

So far there are few systems in operation - about 200 worldwide. In a recent review of the labour implications of FMS, Karl-H Ebel notes, however, that all too often FMS applications are "inserted like an island into an ocean of chaos". The fact is that if the full benefits of FMS are to be realized the entire production process must, first, be brought under control.

The introduction of FMS is not merely an engineering or financial problem. The human factors are perhaps more important than the technical aspects. For example, when the capabilities of the workers and the machines have been combined to best effect, it has been estimated that 60% of the benefits from the installation of FMS are actually derived from the reorganization and the remaining 40% from the hardware. This highlights the importance of addressing the human factor at the design and planning phase. FMS can be very costly and, once installed, layouts cannot be readily changed.

Under FMS the requirements for manual skills decrease and some may become obsolete, while cognitive skills gain in significance. Mechanical and electro-mechanical skilled occupations are key functions for the installation, operation and maintenance of FMS. Workers in these occupations must be trained in electronics and informatics and programming.

It would be wrong to assume that all machinist and operator know-how becomes obsolete under FMS. The complex tasks of launching, testing and modifying new programs require machining experience and practical and theoretical knowledge of materials and machining functions.

In addition, middle management and supervisors are faced with new responsibilities for which they need to acquire the appropriate know-how. The technological cycle has become so short that the recovery of the investment cost becomes uncertain unless management acquires the necessary expertise to fully utilize the new system.

COMPUTER-AIDED DESIGN

Computer-aided design (CAD) has the potential to bring about radical change in the skill requirements of occupations such as engineering and components design. CAD systems consist of a graphics computer screen connected to a computer, providing an electronic drawing board which enables the designer to draw a design with a short set of instructions. Automatic software routines may even propose designs. In theory the skill of designing a product or circuit could be embedded in the software, transforming the designer into a computer operator.

The reality is somewhat different. Based on interviews and observations of computer-aided design systems in aerospace, computer and electronic firms in the US, Salzman and Mirvis concluded that CAD extended the design capabilities of designers but was only a tool for their use, not a replacement for their knowledge, skill and experience. As one CAD trainer put it: "Sure you can train a clerk to become a CAD operator and design a board ... but it'll look like a board designed by a clerk."

The study found that the retraining necessary to operate CAD systems was surprisingly minimal considering their apparent complexity. The average training period was two to three weeks to learn the basics of the system. This usually consisted of three to five days of training classes - either in-house or through an outside vendor - and a couple of weeks of practice. After four months in most cases, and no more than six months in any of the cases, the designers felt that they had fully mastered the system and fully integrated it into their work. Salzman and Mirvis observe that the acquisition of the requisite skill to use a CAD system is a marginal addition to the skills and knowledge of an experienced designer and well within the grasp of those currently employed.

STATISTICAL PROCESS CONTROL

In its 1986 Report, Canada's Automotive Industries Human Resources Task Force describes statistical process control (SPC) as one of the dominant "soft" process technologies shaping automotive production.

SPC is a proactive method of improving quality in the manufacturing process. SPC uses simple statistical techniques to study variation within parts or products and where there are quality problems, to gain an understanding of what is required to correct them.

Several features set SPC apart from previous quality control methods. First and foremost, its application can be handled by production workers, not just by inspectors or the quality control department. Second, SPC can track not simply whether the product is within specifications but also trends within the specification boundaries. As a result, potential problems can be caught even before they result in defective parts.

The Task Force notes that SPC is deceptively simple to describe but is much more difficult to implement. SPC can have a profound impact on the job content and skills of production workers. The mathematical skills required for SPC are not onerous, but for the average worker they are new skills nonetheless. Ideally, SPC supplements a broader team approach to problem-solving. Here, too, new skills are required - skills in communications, group dynamics and cooperative action.

Vehicle assemblers and parts producers in Canada indicate that the cost of training is high and the gains are slow and uncertain. Sophisticated applications can take three to five years for full implementation. While most firms are finding the skills of their workforces adequate, some are struggling. Some firms are requiring higher educational qualifications for all new entrants.

JUST-IN-TIME PRODUCTION AND DELIVERY

Another of the new organizational technologies that could have a profound impact on the automotive sector is just-in-time delivery and production (JIT). The Canadian Automotive Industries Task force report notes that all major North American Automotive assemblers are moving to JIT internally. They are also requiring it of their suppliers as a condition of contracts. However, full implementation of JIT in the Canadian system will take at least 5 to 10 years.

JIT involves producing and delivering products at the specific time they are needed. The underlying goal is to eliminate inventory, making all material part of the work in progress. JIT is more than a better inventory system. JIT is an approach to quality control and production cost reduction. Because there is little or no inventory, all quality has to be good, including the quality of incoming materials, work-in-progress and finished goods. Preventive maintenance becomes more valuable because the increased machine utilization that is often part of the JIT process puts a high premium on machine reliability.

Full implementation of JIT involves far more than more frequent and more prompt deliveries. If parts manufacturers do not start dealing with their own suppliers on a just-in-time basis, JIT will simply be an exercise in shifting inventory from the assembly stage to the parts stage.

As with SPC, a team approach is required to make JIT work. Workers will need a good grounding in communication and group skills. If it is poorly implemented, JIT can raise stress levels in the workforce, especially amongst those workers who have to maintain production in the face of subquality or late deliveries over which they have no control.

RECENT EXPERIENCE WITH NEW TECHNOLOGIES IN INDUSTRY

In recent years there have been a number of studies undertaken which have examined the implications of the diffusion of new technologies for worker and management skills. Some of the studies have surveyed firms in a number of industries; others have focussed on one specific sector. The majority of the studies summarized here are Canadian. However, some European and U.S. studies are also reviewed to explore whether the Canadian experience is unique or consistent with the experience in other developed countries.

ONTARIO TASK FORCE STUDY ON EMPLOYMENT AND NEW TECHNOLOGY

As part of its mandate, the Ontario Task Force on Employment and New Technology in 1985 commissioned surveys of firms across Ontario in more than twenty industries. It was assumed that certain computer-based technologies had the potential for causing significant employment changes over the 1985-1995 period. These included office automation applications, telecommunications applications and advanced manufacturing applications.

The twenty industry sectors chosen were those in which most employment changes might be expected to occur. The autos and parts industries and the mining sector were not included in the survey since they were subject

to separate studies by Employment and Immigration, Canada.

For the survey the manufacturing industries included: iron and steel; metal fabricating; machinery and equipment; aircraft and parts; communications equipment; office and business machinery; and plastics processing. Service industries included: banks and trusts; insurance; government; telecommunications; retailing; management consulting; and computer services.

On the basis of the 180 firms who responded to the survey, the Task Force drew the following conclusions:

- A significant level of new technology had already been adopted. In manufacturing these included computerized financial systems, computerized inventory systems, numerically controlled and computerized numerically controlled machines. In the service sector these involved word processors, microcomputers and data-based management systems.

- Plans for new technology adoption are extensive in the 1985-90 period, encompassing a greater range of technologies and faster rates of adoption than in the past. (See Appendix 1.)

- The forces which are driving the need for the adoption of new technologies over the next decade are perceived to be competitive pressures, cost reduction and changing consumer demands in the manufacturing sector, and increased productivity, competitive pressures and cost reduction in the service sector. (See Appendix 2.)

- When asked to name the three most important factors which could slow down technology adoption over the next decade, manufacturers cited poor economic conditions, financial considerations, and lack of skills to implement. In the service sector, financial considerations, lack of skills to implement and unwillingness to change were seen as the major potential barriers. (See Appendix 3.)

- Generally, firms believe that the adoption of new technology will require employees to have more skills. More training will be required to achieve proficiency, and employees will need to know more about their organization's operations.

- A wide range of managerial, professional, technical and skilled trades personnel were identified as needing more skills and more training to do their work in the future. Many industries expect shortages of these people.

- For manufacturing firms, recruitment is the most commonly cited response to anticipated skills shortages of managerial and professional personnel, such as engineers and system analysts. In contrast, service sector enterprises are most likely to retrain their managers although they too will recruit for technical professionals, followed closely by retraining. Skilled workers in manufacturing and clerks in the service sector are most likely to be retrained to meet shortages.

- In both the manufacturing and service sectors training costs at present range between 2% and 10% of total labour costs. In future, training costs are anticipated to increase slightly as a percentage of labour costs. The proportion of training costs related to the introduction of new technology are likely to stay between 30% and 60% for most industries in both the manufacturing and service sectors. (See Appendix 4.)

ECONOMIC COUNCIL OF CANADA'S TECHNOLOGICAL CHANGE STUDY

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As part of its project on the "Labour Market Impact of Technological Change", the Economic Council of Canada carried out a nation-wide survey of employers in close to 1,000 establishments regarding their experiences with computer-based technological change.

The major findings of this survey are highlighted in a summary report published in 1986 entitled "Working with Technology". The report makes a number of observations with respect to the implications of recent technological diffusion for skills training. These include:

- In the period 1980-85, three quarters of the establishments surveyed reported the introduction of some computer technology. Much of the innovation reported involved low-cost office technologies. Therefore, the impacts of high technology introduced during the first half of the 1980s focussed primarily on white collar jobs.

- The two principal motivations for innovating were to increase productivity and to reduce labour costs. Improvement of product quality was also a motivational factor frequently cited. (Figure 8)

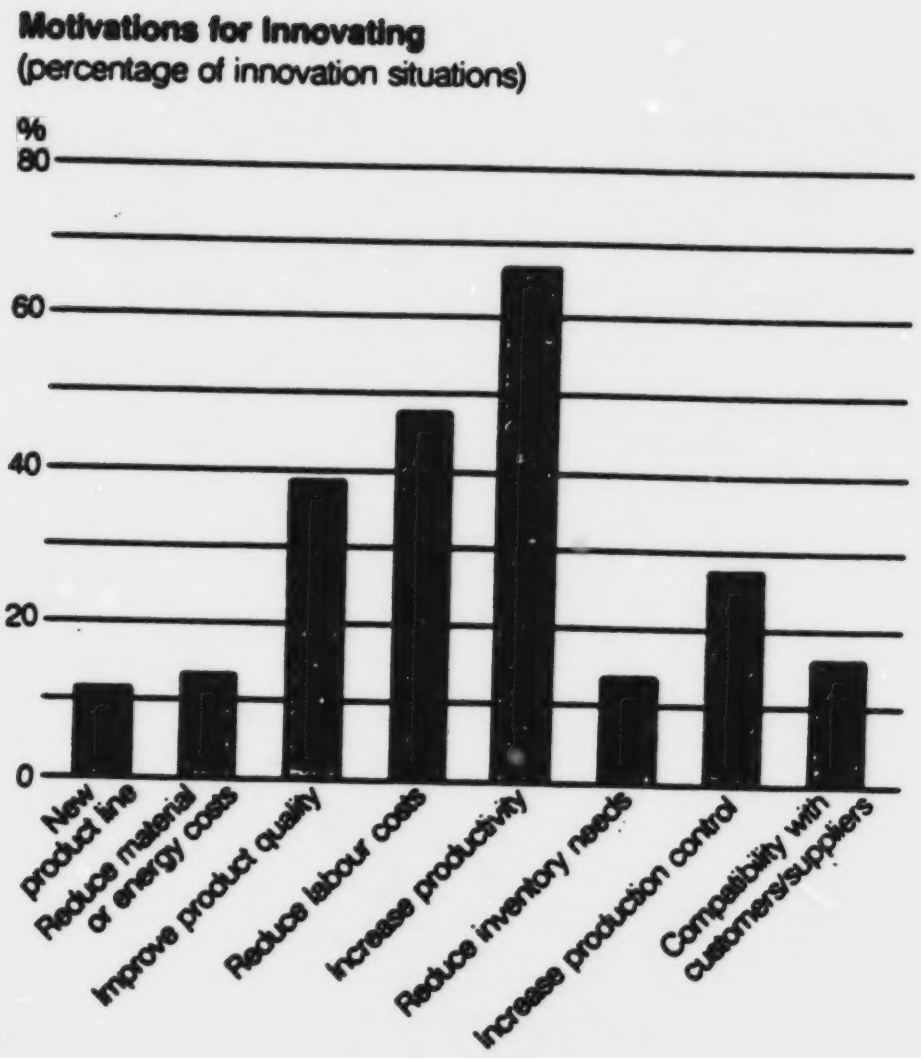
- Survey respondents cited the cost of equipment as the major obstacle to innovation. This finding further emphasizes the role that cost plays in explaining the relatively low incidence of expensive process technologies in the types of innovations introduced in Canadian firms to date. The next most important barriers to innovation were the lack of technically-skilled personnel and an anticipated low rate of return on investment. (Figure 9)

- About 75% of innovating firms reported that technological changes had resulted in a need for new or substantially altered skills.

- The dominant strategy for meeting these new skill requirements was retraining existing workers.

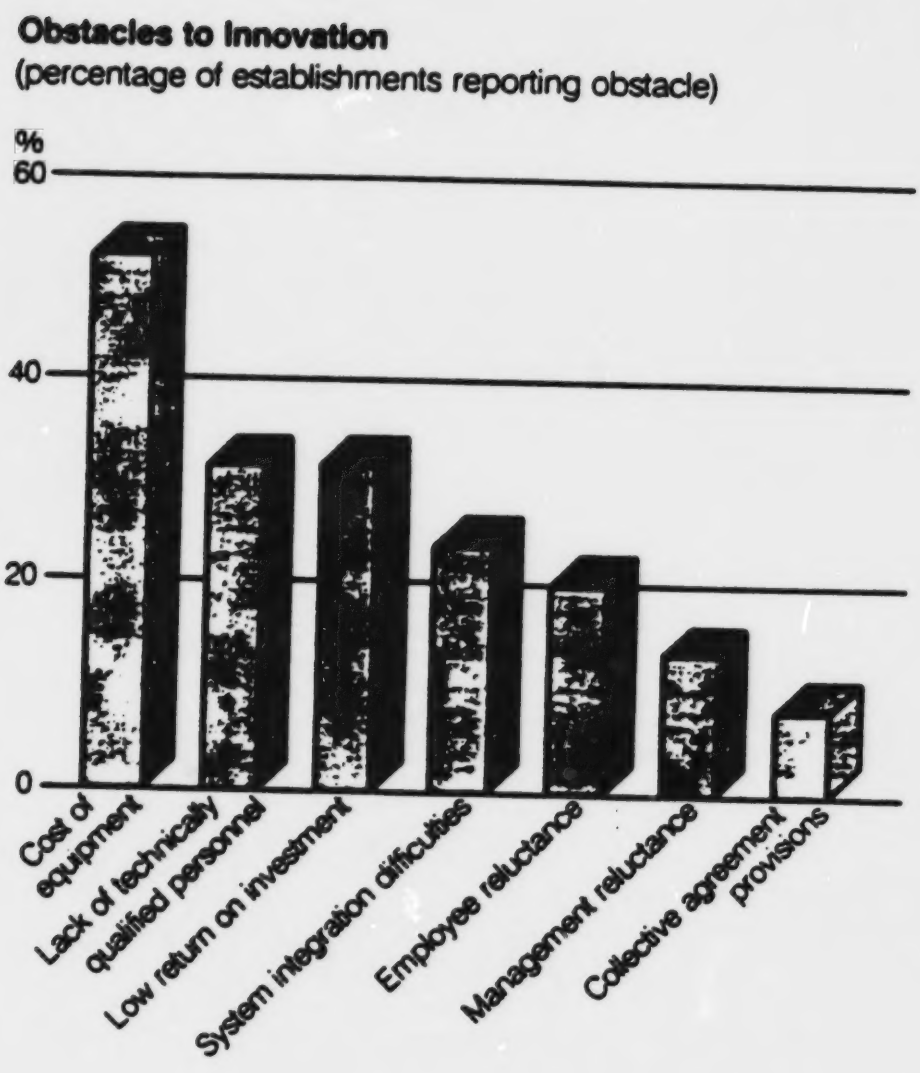
- It was found that short duration, on-the-job training of less than 4 weeks was normally a sufficient training period.

FIGURE 8



SOURCE: BETCHERMAN, G. and Kathryn McMullen; Working with Technology: A Survey of Automation in Canada, Economic Council of Canada, 1986.

FIGURE 9



SOURCE: BETCHERMAN, G. and Kathryn McMullen; Working with Technology: A Survey of Automation in Canada, Economic Council of Canada, 1986.

ECONOMIC COUNCIL OF CANADA
MAKING TECHNOLOGY WORK:
INNOVATION AND JOBS IN CANADA

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The most recent segment of the Economic Council of Canada's project on the "Labour Market Impact of Technological Change" focuses on the impact of new technologies on jobs and the nature of work in Canada.

Making Technology Work: Innovation and Jobs in Canada, released in July, 1987, utilizes extensive projection models to predict technology-driven changes in Canada's labour markets and skill requirements for the 1990-1995 period. Among the findings and conclusions of the report are:

- While almost 60% of technological change in the last five years occurred in the area of office automation, well over half of technological change in the next five years is expected to occur in the area of processing operations, particularly with the application of Computer Assisted Design and Manufacture.

- Companies may have been able to get by without major retraining efforts until now, because the bulk of computer innovations have affected clerical occupations, with a more modest impact on skills. The larger-scale, integrated process-related systems that are expected to spread in the remainder of the decade will almost certainly call for a considerably greater effort in human resource development.

- Case studies illustrate that the presence of a well-trained workforce is critical to the optimal performance of new technologies. Despite this, there is little evidence of major skills development on the part of Canadian industry in response to the computer technologies introduced so far. Evidence suggests that Canadian workers get about 2 hours of in-plant retraining annually, compared with 100 to 200 hours for Japanese workers.

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- Research indicates that the technology-driven retraining that has been carried out has been short duration and unstructured, aimed predominantly at integrating new technologies with existing skills.

- The new technologies are vitally necessary but, alone, they are not sufficient to generate necessary improvements. A well-trained and flexible workforce is equally important. Canadian companies must recognize that training is not a cost but an investment.

CEDEFOP
MICROELECTRONICS
TECHNOLOGY STUDY

A series of case studies was undertaken concerning the introduction and use of microelectronic technology in three EC countries, namely Denmark, France and the Netherlands. The project was commissioned by the European Centre for the Development of Vocational Training (CEDEFOP).

A total of 44 firms (large, small and medium) were interviewed in a number of sectors which provided an opportunity to identify issues related to the use of microelectronics in product innovations, process innovations and information processing. These sectors were the electronics industry; machine manufacturing; graphics industry; paper industry; food, drink and tobacco industry; distribution; and insurance.

A CEDEFOP report, based on these case studies, was published in 1984. It indicates that in E.C. countries, massive training needs exist at all levels with regard to the introduction and long-term management of computer-based technologies, in both factories and in offices.

These training needs can be grouped into four categories:

1) Awareness Training: There is a need for training to make managers aware of the new

technologies, and for training of both managers and workers in the implications of new technologies. Although there is a very general awareness of the new microelectronics technologies among managers, they have problems translating this into specific action. Equally, many managers have a sense that the technologies are too complicated for them to handle. This reflects what has been described as a "chronic and dangerous technological illiteracy" in some European countries.

Managers not directly part of the group in the firm given the task of introducing the new technology often have a problem with the new jargon, which can foster resistance to change.

It was also recognized that there is a need to periodically update the knowledge of engineers and technicians.

2) Attitudinal Changes: Change is an inherently emotional and, therefore, resisted process. Resistance can be compounded if it is perceived to involve a loss of power. Technology that allows workers to exercise more influence on the job can lead to a reduction of power for certain supervisors or managers. This is often given as the dominant reason why lower level management are in many cases inhibitors in the change process.

3) User Training: There is a need to train workers to understand new technology so as to make it possible for them to maintain and modify the system and to give them broad training which would provide a platform for future change.

The training given to operators by the suppliers of new technology was generally short and often regarded as inadequate. It sometimes was equivalent to giving the operator an operating instruction manual.

4) Training for Effective Decision-Making: Managers need training in strategic planning, innovations planning and systems thinking. They also needed training to make effective assessments of the economic justification and choice of new equipment and to implement the new

technology in the most effective socio-technical way.

LAPP REPORT ON TECHNOLOGY TRANSFER IN ONTARIO

In 1985, the Ministry of Industry, Trade and Technology commissioned Philip A. Lapp Limited and Currie, Coopers & Lybrand to carry out a study of technology transfer mechanisms and barriers to technology diffusion in Ontario. The findings were based on structured interviews with 27 Ontario manufacturing firms which were grouped by size (small or large), technology intensity (high, medium or low) and ownership (foreign or Canadian).

Respondents cited their needs for government assistance concerning technology transfer to be (in order of importance): financial assistance; training; information; help in retaining consultants; accessing universities; and attending trade shows.

The study suggests that many Ontario firms do not yet desire new technology. Firms may not be convinced that the returns will be sufficient; they may not feel they have adequate shop-floor skills to make use of the new technology, or they may not understand how to manage the change process.

Both high technology intensity (HTI) and medium technology intensity (MTI) firms reported that they did not have adequate management and worker skills at the beginning to make use of the new technology. Needs of management and workers differ, however. Workers need to know how to operate and repair new equipment. Managers need to know whether the equipment is justified, how to select it, and how to profitably integrate it into an existing operation. Worker resistance to change was not significant. Management resistance to change was a more important barrier.

The Report notes that "if the pace of technological change in Ontario manufacturing industries is not meeting expectations we feel

it is because management is resistant to change. We think it is unlikely that Ontario managers would, on balance, be any better prepared than their workforce to make use of the new technologies in their businesses. Thus, we reason that when managers say their employees need technological upgrading and retraining, they are also asking for help themselves."

Skills problems were addressed primarily through retraining. Also cited as important responses to skills shortages problems were new staff hiring and trial and error experimentation.

With respect to training deficiencies that retard technology diffusion, the Lapp Report recommends:

- development of innovation courses to provide managers with requisite skills on how to manage technical innovation.
- a comprehensive set of training programs, responsive to individual firm needs. The key target group should be medium technology-intensive firms.

BOSTON UNIVERSITY STUDY ON CERTAIN COMPUTER TECHNOLOGIES

To examine the impact of computer technology on skills, Salzman and Mirvis of Boston University examined several types of computer-based technologies in three different types of firms and six occupational groups. The firms were a legal books publisher, an aerospace company, and several electronics and computer manufacturers. The technologies were CAD systems used for mechanical engineering and electronic component design, word processors, personal computers, and management information system used in credit and collection.

Their findings can be summarized as follows:

- Computer-based technologies will not require new skills radically different from existing ones.

- Computer technology requires only an incremental advance in knowledge and skills.
- The "new" jobs still require workers to have a substantial proportion of their existing skills.
- There are important skills that are specific to the organization or the production process that are not replaced by the use of the new technologies.
- The transition to using the new technologies occurs relatively easily when there is support by the firm.
- Since computer skills are add-ons to existing skills, it is normally more cost-effective for the firm to retrain current workers than to replace them.

U.K. MANPOWER SERVICES COMMISSION REVIEW

In 1985, the U.K. Manpower Services Commission undertook a review of recent studies into the effects that the adoption of new technologies is having on occupational skills in the manufacturing and services sectors.

A central conclusion of the review is that the need to learn new skills and understand new technical systems is not confined to a narrow range of technical or technological jobs; such a need exists throughout the workforce.

The following are some of the occupational training implications of implementing new technologies, particularly computer-based technologies.

1) Management Skills: The success of an innovation strategy hinges on management's ability to make technically informed decisions. The decision-making process may be aided by specialist advice but managers themselves must be intimately concerned with understanding the capabilities of new systems, planning their integration with existing equipment and

identifying manpower and skills implications. This need to develop systems awareness may be most acute in senior management because it is here that the most important innovative decisions tend to be taken.

Skill is also needed by management to achieve consensus over restructuring of work roles. Managerial inadequacy with respect to retraining and industrial relations may result in barriers to successful innovation which are every bit as serious as a lack of technical expertise.

New computer-based information systems are beginning to have major effects on management roles. Some supervisory roles have become marginal or redundant. More generally, formalized information systems have constrained the autonomy and the freedom of operations previously enjoyed by many line managers. As such systems become more commonplace, managers at all levels will have to learn how to make effective use of the new equipment and its information. Management inhibitions to working with terminals and keyboards will have to be overcome through familiarization training and systems awareness education.

2) Professional Skills: The consensus of research findings is that new computer-based technology is less likely to de-skill professional work (medicine, law, etc.) than to enhance it. In a lot of cases computers have taken over the routine aspects of the professional work load and have been used to organize data to allow the best possible expert judgements to be made.

3) Technologists: Technologists (engineers, scientists, mathematicians) play key roles as instigators and developers of new technology. Often the technical expert takes on the role of "innovation champion". To be effective, technologists may have to acquire skills in putting complex technical issues to decision-makers and implementors of the technology. In addition, technologists will increasingly find themselves requiring the skill to work in multi-disciplinary environments.

4) Technician Skills: Two general trends may be discerned relating to the impact of technical change on technicians. The first is the increased demand for multiple skills experience in a range of disciplines. The enormous complexity of integrated systems demands that technicians possess both theoretical knowledge and practical diagnostic skills in a variety of fields. The second trend is for polarization between higher and lower level technician skills. Higher level skills have become much more complex; lower level skills more routine.

5) Operator and Maintenance Skills: Despite the trend towards automation through the more widespread use of computer numerical machine tools and integrated machining centres, operator skills are not simply abolished. Some jobs are reduced to mundane machine minding. However, operators are often required to part-program and also to master more complex servicing routines. With respect to maintenance skills, new technology maintenance demands a high level of diagnostic competence based on a broader range of theoretical knowledge and practical skills experience.

6) Office Skills: Office workers with previous keyboard competency, such as typists, have been trained easily to work with new technologies such as word processors. Clerical jobs require less ability to perform complex, detailed calculations although they may now involve interpreting figures, operating routine programs, and information retrieval. To a large extent the new and increasingly standardized office techniques have resulted in a loss of skill specificity in office jobs.

COPS AUTOMOTIVE STUDY

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The Report of the Canadian Automotive Industries Human Resources Task Force was submitted to the Federal Minister of Employment and Immigration in 1986.

The Report highlights the massive training challenge for the auto industry over the next

5-10 years as it responds to international competitive pressures. Three elements in the strategy being pursued by the North American industry have major implications for skills training. These are:

- efforts by the vehicle manufacturers to restore manufacturing competitiveness by matching Japanese innovations in production management and computerized automation;
- efforts to improve the parts sourcing system means that the competitive pressures on parts suppliers are every bit as acute as in the assembly sector;
- improvements in product technology to rival the best European manufacturers.

As a result of these measures, the Task Force found that skills requirements in the industry overall are rising. Workers and managers are being required to master more skills than ever before, use these skills more frequently, and adapt these skills more often to changing situations. It is the view of the Task Force that the existing workforce will be capable by and large of making the transition to the higher level of skills required in the future, provided they have adequate training.

The Report identifies training needs in four areas, namely basic skills, analytical skills, interpersonal skills, and technical skills. It estimates the industry's training bill will rise from $75 million today to $200 million by 1990. Although workers may by then be receiving 40 hours training annually, according to Canada Employment and Immigration officials, this will still be less than the present Japanese average.

1) Basic Skills: The report found that 29% of independent auto parts companies responding to the Task Force survey reported that the reading and writing skills of their workforce were inadequate; 36% reported inadequacies with respect to the mathematical skills of their present workforces. There is strong and widespread belief in many companies that the public schools are doing only an adequate job. Retraining involves short, in-house courses or

refresher courses in community colleges or adult education programs.

2) Analytical Skills: The auto industry has never faced a training challenge as large as that posed by the rapid introduction of statistical process control (SPC). To be effective, SPC must be taught to everyone from managers to workers on the shop floor. Most companies are organizing their own courses.

3) Interpersonal Skills: Adequate interpersonal training is critical to the success of quality circles or problem solving teams. Training often involves short 8-16 hour courses in group dynamics.

4) Technical Skills: This is the area where the auto industry has traditionally provided the most on-the-job and institutional training. This will continue to be the case. However, two new training challenges in the areas of technical skills involve skills upgrading (especially electronics repair) and equipment-related training. Companies have formal upgrading programs and use community colleges and private trainers. The Task Force notes that many companies are concerned about the costs of skills upgrading; both firms and workers are concerned about obsolete trainers. With respect to equipment-related training, vendors are increasingly expected to provide training on new equipment.

5) Skills Shortages: Heading the list of occupations that were likely to expand most quickly over the next five years were skilled trades people, especially electricians. The Task Force notes that concerns are already being raised about the difficulties that could be experienced in hiring skilled workers. If the experience of the past few years is an indicator, skill shortages could lead to production cutbacks, especially among independent parts producers. The marked lack of human resource planning among small and medium-sized parts producers suggests, however, that no precise advance signals will be fed into the training system until the shortages occur.

6) Role of Government: As their annual training bill approaches $200 million, the auto

industry is looking to government to pick up a bigger share. GM advocates a training tax credit. The Task Force notes that training for automotive workers will benefit other industries as well because there is substantial mobility into and out of the industry.

COPS METAL MINING INDUSTRY STUDY

Given world-wide excess capacity for minerals and a declining intensity of mineral use, the Canadian industry has emphasized productivity improvement to remain competitive. In part, this is being realized through the adoption of new technologies. The 1986 Canadian Occupational Projection System (COPS) study of the metal mining industry points out that these include new mining methods, the development and adoption of new drilling equipment, computer-aided mining machinery, the use of underground computer terminals, and more sophisticated milling systems.

The move from manual to more mechanized operations has resulted in a proportional reduction in mining occupations (miners, drilling and blasting occupations, mining labour) but has raised the skill levels required to repair and maintain more sophisticated machinery and process control systems. The general trend toward more mechanization in both mining and milling has resulted in requirements for more engineering technologists and technicians. The increasing use of new computerized process control results in the need for upgrading skill levels for both electricians and instrument technicians. Electronic technicians will likely gain in importance as more electronics are utilized.

The movement is towards a more educated and more technically skilled workforce. The results of a 1985 survey of the industry indicate that the major portion of skills enhancement is taking place through retraining rather than new hires. This appears to be a manageable problem at current levels of activity. However, if the rate of adoption of new technologies and production processes picks up or if there is an

increase in economic activity, difficulties will be encountered in attracting the required personnel for some of the highly skilled jobs.

The training problem is made more difficult for the industry by the high degree of worker mobility in and out of the metal mining sector.

EXPERIENCE OF THE ONTARIO TECHNOLOGY CENTRES

Ontario's Centre for Advanced Manufacturing (OCAM) has noted several technology-specific challenges that are common to most industry groups in Ontario. With respect to skills training, these are:

- Many senior managers in Ontario have little or no experience or background with new technologies. These managers have not yet reached a comfort level with the new technologies.

- Many firms have difficulty in quantifying the business returns that will accrue from the adoption of advanced manufacturing technology.

- Approximately 90% of Ontario manufacturing firms are "small" firms employing fewer than 250 people. Of these, possibly 70% have no engineers on staff and as a result have a reduced ability to track, evaluate and adopt advanced manufacturing technology.

The Ontario Centre for Farm Machinery and Food Processing Technology has observed that a high percentage of the medium and small companies in its two target industries appear to lack "technical familiarity". In particular, many of these firms:

- have few, if any, qualified technical staff;

- appear to have a fear of technology;

- have outdated production methods or technologies;

- appear to be unaware of the newer technologies appropriate to their business or industry; and

- have an inability to define their technological needs and opportunities.

The Centre is convinced that there are tremendous opportunities for smaller companies to cater to specialized niches in the burgeoning market for processed convenience foods in Ontario. However, this will necessitate investments in productive new technologies. Unfortunately, in too many instances, the small and medium firms perceive money spent on technological upgrading to be an expense rather than an investment.

In light of these considerations, the Centre lays stress on:

- providing technology awareness and training for smaller firms through outreach programs, and

- providing demonstration of new technologies appropriate to the sector.

OVERVIEW OBSERVATIONS

A number of broad conclusions can be drawn from the review of recent studies that have addressed the experience of industrial adaptation to new technologies. These are:

1) THE NEED TO RESHAPE THE MANAGEMENT CULTURE: Technology management skills are the major single element determining the speed and effectiveness with which new technologies are implemented in a given firm, sector, or economy. Management decisions are not only at the heart of technology choices, but also determine the nature of the resulting workplace organization and worker retraining. Consequently, improving management skills in the awareness, evaluation and implementation of new technologies must be the counterpoint at all times of measures to upgrade workforce skills.

2) THE IMPORTANCE OF APPROPRIATE WORKFORCE SKILLS: Concern about the lack of availability of skilled workers is consistently one of the major factors slowing the introduction of new technologies. Engineers and technicians, especially those familiar with new technologies, are often a critical bottleneck, and one that often cannot be addressed through new hiring. Retraining is widely cited by firms across a large number of sectors in many jurisdictions as a feasible and desirable response to skills bottlenecks. In fact, since there are important skills that are unique to an organization which would have to be learned by a new hire, retraining is often more cost-effective than replacing existing workers, even if replacements can be found.

3) THE CONTINUED RELEVANCE OF SHORT-TERM ON-THE-JOB TRAINING: There has been a very widespread introduction of computer-based technologies in Ontario's manufacturing and service sectors over the past five years. The evidence in Ontario as in other jurisdictions points to the effectiveness of on-the-job short training courses as the prime means of absorbing and integrating new technologies into the existing workforce. This reflects the fact that technological change has essentially involved stand-alone machines or simple terminals linked into relatively simple networks.

4) THE IMPORTANCE OF BASIC VOCATIONAL SKILLS: The anticipated acceleration in the growth of office networks, complex integrated manufacturing systems and organizational technologies raises the possibility of a widespread phase of re-education and re-training. In turn, this calls attention to the importance of a workforce that possesses or can acquire the basic vocational skills as an underpinning for a recurrent cycle of working and learning.

5) UP-TO-DATE TRAINERS: Concerns are expressed about trainers in technical disciplines where the pace of scientific discovery is such that the half-life of a trainer's knowledge may be between three and five years. Concern is also expressed about training that takes place on out-of-date equipment.

6) ADEQUACY OF THE TRAINING INFRASTRUCTURE: One recent study has suggested that 10% of Canada's manufacturing workforce of two million people may be involved in retraining in the early 1990s simply as a result of the increasing adoption of computer-integrated manufacturing. The same study suggests this could involve a training bill of $400 million annually. These possibilities raise questions not only about training costs but also about the adequacy of the training infrastructure which traditionally has not been geared to re-education of the workforce on a mass scale.

OVERVIEW OF SKILLS TRAINING PROGRAMS

A number of provincial and federal programs have been developed which are designed to provide workers and firms in Ontario with assistance in skills upgrading. Some of these programs deal specifically with skills issues arising from the technology diffusion process. Others have more general objectives, but can often be used to assist workers or firms to respond to situations of technological change.

APPRENTICESHIP TRAINING

Apprenticeship training in Ontario is a system of combined on-the-job and in-school training of highly skilled workers. Apprenticeship is a provincial program which receives federal funding support for the in-school training and income support of apprentices. Ontario administers the program and legislates the training content.

23,400 apprentices received in-school training in Ontario in the 1985-86 fiscal year, at a cost of $26.8 million. In 1986-87, 25,500 apprentices received in-school training at a cost of $32.8 million.

Apprenticeship training is legislated under the provincial Apprenticeship and Tradesmen's Qualification Act. Although the training process is of long duration, averaging two to five years, only 10% of the training is done in

a classroom setting. The average course length for the in-school portion of the training is eight weeks.

At the end of 1986, there were about 39,000 apprentices registered in Ontario, about 6,000 of whom were in the industrial trades such as tool and die maker, industrial electrician and general machinist. It is these skilled workers in the industrial trades who are already experiencing the impact of rapid technical change in industries such as the auto industry.

It is clear that to be effective in the future, apprenticeship training must place increasing attention on building a firm foundation for a lifelong process of periodic skills upgrading. If necessary, skilled tradespeople must be helped to adjust to the potential of skills obsolescence. One key element is to ensure that the curriculum for industrial trades contains a core of basic vocational skills, to provide the basis for future retraining.

Introduced as a complement to time-based apprenticeship training, modular training is a system where trainees can progress at their own rate through a series of modules designed to develop or improve their competence in certain trades or occupations. Modular training programs may be province-wide or company specific or sector specific.

Current funding for modular training is $1.5 million annually, with trainees registered in some 37,000 modules of training.

The modular training system has provided a flexible method of meeting both basic and new skill needs in companies, especially in the mining and petrochemical sectors. Certification provides a basis for measuring progress and achievement, while also giving employees portable skills.

Conceptually, modular training meets many of the needs that will be encountered by workers and firms in a world of fast-paced technological change. It is important, therefore, that many of its strengths continue to be reflected in the evolving mix of programs offered by governments.

TRAINING CONSULTING SERVICES

To train successfully, a firm must be aware of its human resource needs and able to implement training strategies. The majority of our firms have no human resource strategies and little training expertise. This is particularly true for small businesses.

Because smaller businesses employ the majority of Ontario workers, this has serious implications. If these firms are not training, then most of our workers lack the opportunity to develop the skills needed to meet competition and change.

Training is limited in smaller firms usually because they lack the capability. Larger firms often have in-house resources to recognize needs and plan, develop and provide training; smaller firms do not. What's more, private sector services to put training programs in place are limited. Such services as there are have tended to be for turn-key training projects for large companies.

The Ontario Ministry of Skills Development program has designed a $15 million program of training consulting services to help Ontario businesses, particularly small and medium-sized firms, to identify their training needs and to develop and implement training plans. The service is available through 50 Ontario Skills Development Offices across the province.

These Offices provide a wide range of training consulting services:

- NEEDS ASSESSMENT which helps employers recognize and specify their training needs.
- TRAINING PLAN DEVELOPMENT which sets out the kinds of training needed to meet the levels of competence specified in the assessment. It takes into account experience, theoretical knowledge and technical skills, standards of performance and, if necessary, certification.

- TRAINING AND PLAN IMPLEMENTATION which assists in finding the most appropriate training: on site; in a training institution; or provided by a private consultant.

- FOLLOW-UP which ensures that the standards set out in the training plan are met.

The Offices are working to achieve a significant increase in the number of new clients served, particularly those with fewer than 200 employees. More than 10,000 firms are expected to benefit annually. Two-thirds will be firms which have offered little or no training in the past.

ONTARIO SKILLS

Large firms have received most of government's financial support for training. More than 57% of companies with 500 or more employees have benefited from government funding. Less than one-third of all companies with fewer than 200 employees have done so.

Nevertheless, government support is a vital factor in the training decision for smaller firms. The proportion of the total training budget funded by government gets larger as the size of the company gets smaller. The majority of the smallest companies undertaking training say that government funding accounts for more than 40% of their training expenditures. Funding for training must be directed at those firms which need it most, that is, where the largest increases in training activity can be expected.

Ontario Skills is a $34 million Ontario Ministry of Skills Development program which provides incentives to employers for the workplace training they undertake. The incentives help with direct instructional costs of worker training and upgrading through training courses, usually of short duration.

Some funding under the Ontario Skills program is targeted to management training, particularly in small and medium-sized firms.

This initiative recognizes that managers need assistance in introducing and supervising new technologies and productivity-improvement processes.

To the extent that the implementation of new technology continues to necessitate short duration training (as has been the experience of the past), the Ontario Skills program will remain a highly relevant program for facilitating the process of technology diffusion in Ontario.

TRADES UPDATING

The $4 million Trades Updating program of the Ontario Ministry of Skills Development helps individual skilled tradespeople and journeymen by providing short-term training designed to keep skills up-to-date.

This program was conceived to respond to the ongoing demands of technological change. For the program to be effective, it is essential that journeymen have access to training in state-of-the-art techniques and equipment by up-to-date instructors. It also may be necessary for tradespeople to receive practical and theoretical training in a number of disciplines in addition to their primary area of expertise. Some updating courses could involve as much as 1,000 hours of new training.

ONTARIO BASIC SKILLS

Both literacy and basic mathematics are indispensable building blocks of skills development. Far too many Ontario workers lack these basic skills. Twelve per cent have less than grade nine education; they often do not have the basic skill levels essential in a technological world. Furthermore, in an information economy, basic skills go beyond simple math and reading and writing skills. For instance, they include computer literacy and communications skills.

The Ontario Basic Skills program helps our workers adapt successfully to a changing world of work. This program is designed to help those people in the workforce, or entering the workforce, who lack or need to upgrade their basic literacy and numeracy skills. Program funding is $23 million a year.

Upgrading of basic skills is essential if all Ontarians are to participate in tomorrow's high technology, information society. It is also essential if firms in certain industries are to succeed in adopting technologies such as JIT and SPC, while retaining their existing workforces.

ONTARIO TECHNOLOGY CENTRES

The Technology Centres were established in 1982 as crown agencies for a five year period. There are five Centres: Microelectronics (Ottawa); Advanced Manufacturing (CAD/CAM - Cambridge); Robotics (Peterborough); Canada/Ontario Centre for Advanced Manufacturing (Windsor); Resource Machinery Technology (Sudbury); Automotive Parts Technology (St. Catharines); and Farm Machinery and Food Processing Technology (Chatham).

The Centres were established to promote and enhance the competitiveness of Ontario manufacturing industry through facilitation of the application and diffusion of existing technology. Their mandate includes:

- consulting services to encourage and assist in the development of advanced technology products;
- training programs in advanced technology to industry;
- information, seminars, demonstration, and technology awareness activities; and
- financing for company start-ups and the application of technology products and processes by Ontario manufacturers.

The services which have evolved in the Centres are split among these four major activities; however, the training provided is relatively narrow in its application. Two of the Centres (Resource Machinery and Farm Machinery) have lacked both the mandate and the resources to provide training to managers in the effective application of new technologies in their sectors. The training emphasis at the other three Centres is on applications training, demonstration programs and technology evaluation training usually linked to specific high-tech machines. There is some training linked to implementation but it is not systematic or comprehensive and generally does not address the issue of integrating the new technology to best effect into the firm's production process, or how workers should be trained to put the new system to best use.

FEDERAL PROGRAMS

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1) Skill Investment: The Skill Investment program is an option within the Canadian Jobs Strategy. The objective of the program is to help workers threatened by technological or economic change to train for the future and to assist firms that want to provide employees with retraining. The federal government subsidizes training costs and wages during the period of retraining which can be up to three years. The retraining under this program must be directed towards jobs in demand.

Expenditure under the Skill Investment program in Ontario was about $3 million in the 1985-86 fiscal year. In 1986-87, approximately $12 million was allocated to this program in Ontario.

2) Skill Shortages: This program provides employers with wage subsidies to train workers in skills that are designated as being in short supply. Assistance is available for both on- and off-the-job training, and for both full- or part-time training.

The federal government spent $31 million in Ontario under this program in fiscal 1985-86. $20 million was allocated for 1986-87.

IMPLICATIONS OF TECHNOLOGY DIFFUSION FOR SKILLS TRAINING IN THE FUTURE

The Task Force on Labour Market Development noted in 1981 that the "training system at the present time is not fully capable of meeting the demands that will be placed on it during the 1980s." The persistence of a number of recurrent problems, especially with respect to industrial training, tend to reinforce the accuracy of that prediction. These problems include:

- ongoing skills shortages and some critical skills bottlenecks;
- the failure to address the skill needs in managing new technologies effectively;
- the widespread problems experienced by firms in retraining existing workers because of inadequate basic skills; and
- the failure of the apprenticeship system to keep up with new skill demands or to provide a basis for ongoing upgrading.

The fact that the strains on the training system posed by widespread technological change have not been more severe is probably a reflection of a number of mitigating factors.

The first is the reciprocal relationship between the skills and technology. Although certain aptitudes, skills and experiences are often essential for the generation and use of given technologies, there is a high degree of agreement among experts that the new

technologies are not deterministic in necessitating certain rigid combinations of skills if they are to be successfully implemented. New technologies can be implemented in a number of different ways with a range of differing impacts on skills and skills training. Equally, the existence of given skills in an organization, or the potential for retraining, will affect the way the technology is implemented.

Second, it should not be forgotten that in the post World World II period there has been a general expansion in educational requirements for formal employment, not as a function of the expanding skills inherent in the jobs themselves, but as a result of the relative overabundance of over-educated applicants seeking employment. Undoubtedly, this has facilitated the ease of adoption of technology in the recent past and is likely to help future adjustments.

Third, it has been argued that the relative lack of strain on the training system is more a reflection of the lags in implementing some of the new technologies in Canada. Harvey and Blakely suggest that the most significant changes in the Canadian occupational structure are yet to come. The polarization of the manufacturing workforce into skilled professionals at the top, the growth in minimal skill jobs at the bottom and a decline in middle level jobs has been delayed by the following factors:

- The exchange rate has given Canada a wage advantage relative to the U.S. This has slowed the pressure for advanced manufacturing systems, but will not stop it.

- There has not been the same erosion of collective bargaining in Canada as in the U.S.

- Public sector employment has not yet been put under any significant squeeze in Canada despite the persistence of a large federal deficit.

Finally, since 1981, there have been extensive changes in federal and provincial

programs to try to ensure that the industrial training system becomes more responsive to the needs of firms and workers.

ACCELERATING PRESSURES FOR CHANGE

The pressures for change in work and skills will intensify in the near future.

A 1987 article in the Economist made the prediction that, over the coming five years, four out of every five people in the industrial world will be performing jobs differently from the way they have been done in the previous 50 years. And most people, sooner or later, are going to have to go back to school, to learn how.

Microelectronics and computer-based technologies will continue to have profound and simultaneous impacts on a wide range of manufacturing industries and service sectors in the Ontario economy over the next decade. Certain organizational technologies such as statistical process control and just-in-time production and delivery which are now reshaping automobile production should have widespread application in the manufacturing sector. The application of advanced materials and biotechnology will begin to affect products and processes in a few industries, and could begin to have a potentially significant indirect negative impact on parts of Ontario's resource and agricultural economy.

The Economic Council of Canada recently confirmed that, throughout the 1970s and 1980s, those sectors utilizing higher technologies outperformed the mid- and low-technology sectors in employment growth, output and efficiency. For many firms, the pressures of international competition will continue to place a premium on early adoption of new technology, since this should translate into high growth, few competitors, high profit margins, and high export potential. For managers, this will necessitate understanding and mastering many of these new technologies and putting them to most

effective use. This may involve specific training or upgrading of skills such as technical awareness, technology evaluation and technology management.

Large segments of the labour force will continue to require extensive training and retraining in computer-related skills. Computer-based technologies will impose more sophisticated skill requirements on individual jobs and will shift the distribution of employment in favour of more advanced, flexible and multi-skill worker capabilities. Part of the training and retraining challenge will be the large numbers of people who may be affected by change without having received sufficient basic vocational training.

Another source of pressure for retraining is the fact that, as a result of demographic trends, fewer young people will join the labour force. This, combined with fewer skilled immigrants, will mean that Ontario will not be able to count on these sources to the same extent as in the past as a source of specialized and up-to-date skills. As such, in future, the economy will rely to an unprecedented extent on adult workers to adapt, retrain themselves, or be retrained.

There is an active debate among international experts as to whether there will be fundamental change in existing practices of work organization and training. This controversy can be summarized as follows:

- The revolutionary view is that the demands of the new technology are going to dramatically affect education and training arrangements.

- The reformist view is that new technology simply provides a new focus for revisiting well-defined training issues that have been the subject of debate for many years, such as lifelong learning, broad-based versus specialized training, the relationship between education and training, etc.

- The conservative position is that new technology does not require fundamental modification to education and training

systems, but rather simply the types of piecemeal and steady changes that have characterized past practice.

Whatever viewpoint is taken, there is agreement that, as a minimum, training systems need continuous fine-tuning if they are to remain relevant and effective.

The challenge facing Ontario's education and training system is a shared one. Meeting it depends on the leadership and cooperation of all participants in the system, including educators and institutions, governments, business and individuals. In particular, joint effort and initiative should be shown in:

- Promoting the role of training in technological change.
- Ensuring that the training system, both public and private, actively assists businesses in defining and planning for their technology needs.
- Placing greater emphasis on retraining those already in the workforce to provide the necessary specialized and up-to-date skills.
- Developing apprenticeship training programs which provide a strong foundation in teamwork and flexibility, and which provide ongoing access to skills updating.
- Making adult re-education in basic skills available to all who need it.
- Developing a management culture in Ontario industry which is supportive of and conducive to leadership in technology implementation.
- Ensuring both an adequate supply and appropriate retraining of technicians and technologists.
- Ensuring that community colleges and universities maintain up-to-date staff, skills and equipment.
- Ensuring, through the establishment of the new Ontario Training Corporation, that firms have access to relevant training materials.

APPENDIX 1

ADOPTION OF NEW TECHNOLOGIES
BY SELECTED INDUSTRIES
IN ONTARIO, 1985 TO 1995

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies		
	Before 1985	1985-1990	1990-1995
I. SERVICE			
Customer Sales and Service Applications			
Automated Teller Machines	41	31	16
Automatic Cheque Verification	19	30	12
Pay by Phone	0	5	43
Automatic Debit/Credit Systems	40	17	21
Computerized Loan Qualification and Approval	19	57	0
"Smart" Cards (with installed microprocessors)	0	7	27
Home Banking	5	17	33
Connection to Retail Store Point of Sale Network	7	23	16
Computerized Trust Management	27	16	5
Computerized Pension Management	33	22	5
Securities Transfer/Stock Holder Services	27	27	16
On-Line Policy/Client Data Bases	68	33	6

APPENDIX 1 continued

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies: Before 1985	1985-1990	1990-1995
Customer Sales and Service Applications cont'd			
Computerized Insurance Needs Analysis	34	55	6
Computerized Contract Generation	48	42	6
Electronic Claims Processing Systems	50	39	0
Automatic Insurance Verification	49	28	2
Computerized Rating/Underwriting	30	67	0
Brokerage Management Systems	38	44	2
On-Line Terminal for Group Insurance Customers	0	41	21
Others	6	10	2
Customer and Service Delivery of Service Delivery Technologies			
Computerized Service Order Processing	30	54	0
Computerized Client Accounts	76	27	0
Automated Diagnostics (Remote Maintenance)	52	23	16
Customized Telecommunications Systems	36	0	0
Voice Synthesis Applications	0	20	36
Voice Recognition Applications	0	36	21
Installed Customized Software Systems	83	45	8

APPENDIX 1 continued

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies		
	Before 1985	1985-1990	1990-1995
Customer and Service Delivery of Service Delivery Technologies			
Installed Customized Hardware Systems	45	55	8
On-Line Client Access to Data Base	30	32	48
On-Line Interactive System with Clients	36	38	36
Direct Data Entry from Field	69	36	0
Electronic Service Delivery	25	34	7
Electronic Processing Service Request	45	19	7
Other	0	3	0
Design Technologies			
Computer-Aided Design (CAD)	15	29	3
Computer-Aided Engineering (CAE)	12	24	3
Computer-Aided Mapping	33	35	0
Computer-Aided Project Management	59	41	0
Fourth Generation Computer Languages	35	55	9
Other	5	4	0

APPENDIX 1 continued

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies: Before 1985	1985-1990	1990-1995
Electronic Funds Transfer (EFT)			
Electronic Funds Transfer (EFT) Interbranch	50	33	17
Electronic Funds Transfer (EFT) Interbranch	44	16	23
EFT Corporate Accounts	24	26	23
EFT Commercial and Retail Accounts	14	22	17
Other	0	0	4
Technologies Within the Store			
Computerized Inventory Control	47	45	5
Office or Office Automation Technologies			
Mainframe/Minicomputers	86	20	3
Word Processing	95	16	4
Electronic Filing	31	52	8
Microcomputers/Personal Computers	88	18	5
Interval Data Base Management Systems	63	35	4
Local Area Networks (LANs)	28	56	7
Computerized Decision Support Systems	36	48	12
Voice Activated Computers	2	22	40

APPENDIX 1 continued

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies		
	Before 1985	1985-1990	1990-1995
Office or Office Automation Technologies			
Artificial Intelligence/Expert Systems	3	20	38
Integrated Work Stations	11	60	18
Data Base Services (External)	73	18	0
Home Terminals	17	29	0
Other	2	2	2
Telecommunications Technologies			
Private Automatic Branch Exchange (PABX)	51	32	8
Electronic Mail	39	50	10
Voice Mail	5	40	24
Facsimile with Built-in Microprocessor (FAX)	28	30	19
Satellite/Microwave Systems	8	12	28
Videotec	14	20	24
Video Conferencing	10	33	29
Fibre Optics	3	27	24
Other	2	1	2

APPENDIX 1 continued

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies		
	Before 1985	1985-1990	1990-1995
II. MANUFACTURING			
Design and Product Technologies			
Computer-Aided Design (CAD)	14	51	12
Computer-Aided Engineering (CAE)	24	28	15
CAD/CAM Integration	7	28	27
Manufacturing Planning and Control Systems			
Computerized Financial Systems	79	23	5
Computerized Order Entry/ Inventory Control	67	36	7
Computer-Aided Process Planning	33	53	15
Manufacturing Resource Planning Systems (MRP)	22	51	15
Automated Shop Floor Data Collection	15	52	23
Computerized Decision Support System	14	52	19
Computerized Maintenance Planning and Control	12	55	20

APPENDIX 1 continued

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies		
	Before 1985	1985-1990	1990-1995
Manufacturing Process Technologies			
Numerically Controlled Machines (NC)	65	25	8
Computer Controlled Machines (CNC)	41	41	16
CAD Directed CNC	6	33	30
Computerized Process control Systems	33	39	7
Computer-Aided Inspection and Testing	32	51	14
Robotic Applications	14	39	26
Flexible Manufacturing Technologies	3	24	12
Computer Integrated Manufacturing (CIM)	8	24	14
Material Handling Technologies			
Automatic Bulk Handlers/Feeder Systems	35	17	9
Automated Conveyor/Vehicle Systems	25	21	10
Automated Storage and Retrieval	1	13	17
Computer Controlled Conveyor/Vehicles	1	7	10
Automated Warehouse	4	9	14

APPENDIX 1 continued

Technologies	Percentage of Responding Firms Planning to Adopt New Technologies		
	Before 1985	1985-1990	1990-1995
Telecommunications Technologies			
Facsimile (FAX) Link: HO/Plant(s)	48	21	7
Computer Link: HO/Plant(s)	44	33	8
Computer Link: Suppliers/Customers	19	50	14

SOURCE: BOGGS, W. and R. White (Chairpersons); Report of the Ontario Task Force on Employment and New Technology. 1985, p. 101.

APPENDIX 2

FACTORS DRIVING SELECTED INDUSTRIES TO ADOPT NEW TECHNOLOGY

		Driving Force, Ranked in Descending Order of Importance		
		First	Second	Third
Manufacturing				
291	Iron and Steel	Competitive Pressures	Productivity/Management Information/Lower Costs	Increase Quality
304	Metal Stamping, Pressing and Coating	Lower Costs	Competitive Pressures	Increase Quality
306	Hardware, Tool and Cutlery	Competitive Pressures	Customer Demands for Changes	Lower Costs
309	Miscellaneous Metal Fabricating	Lower Costs	Competitive Pressures	Customer Demands for Changes
315	Machinery and Equipment	Lower Costs	Competitive Pressure/ Customer Demands for Changes	Increase Productivity
318	Office and Store Machinery	Competitive Pressures/ Customer Demands for Changes	Increase Quality	Strategic
335	Communications Equipment	Competitive Pressures	Lower Costs	Increase Productivity/ Enter New Markets/Growth
321	Aircraft and Aircraft Parts	Competitive Pressures	Customer Demands for Changes	Strategic
165	Plastics Fabricating	Competitive Pressures	Increase Quality	Strategic/Enter New Markets/Growth

APPENDIX 2 continued

		Driving Force, Ranked in Descending Order of Importance		
		First	Second	Third
Services				
701	Chartered Banks	Competitive Pressures	Increase Management	Increase Productivity
701	Trust Companies	Lower Costs	Competitive Pressures	Increase Skills and Organizational Capacity
721	Life Insurance	Competitive Pressures	Customer Demands for Changes	Increase Productivity/ Enter New Markets/Growth
721	General Insurance	Competitive Pressures	Increase Productivity	Customer Demands for Changes
735	Insurance Brokers	Competitive Pressures	Increase Productivity	Lower Costs
909	Federal Government	Increase Productivity	Increase Skills and Organizational Capacity	Lower Costs/ Increase Skills and Organizational Capacity
931	Provincial Government	Increase Productivity	Customer Demands for Changes	Increase Management Information
951	Local Government	Increase Productivity	Lower Costs	Competitive Pressures/

APPENDIX 2 continued

		Driving Force, Ranked in Descending Order of Importance		
		First	Second	Third
Services continued				
544	Telephone Systems	Increase Quality/ Skills and Organizational Capacity	Increase Management Information	Customer Demands for Changes/Lower Costs/Enter New Markets/Growth/ Obsolescence
545	Telegraph and Cable Systems	Increase Productivity	Increase Skills and Organizational Capacity	Enter New Markets/Growth/ Customer Demands for Changes
631	Food Stores	Lower Costs	Competition	Increase Productivity
642	General Merchandise Stores	Lower Costs	Competition	Increase Productivity
853	Computer Services	Customer Demands for Changes/Lower Costs	Enter New Markets/Growth	Increase Skills and Organizational Capacity
867	Management and Business Consultants	Competitive Pressures	Lower Costs	Increase Management Information

SOURCE: BOGGS, W. and R. White (Chairpersons); Report of the Ontario Task Force on Employment and New Technology. 1985, p. 108.

APPENDIX 3

FACTORS IMPEDING THE RATE OF NEW TECHNOLOGY ADOPTION, SELECTED INDUSTRIES

		Impeding Factors, Ranked in Descending Order of Importance		
		First	Second	Third
Manufacturing				
291	Iron and Steel	Lack of skills and know how to implement	Ability to finance	Competitive environment
304	Metal Stamping, Pressing and Coating	Costs of new technology	Ability to finance	Competitive environment
306	Hardware, Tool and Cutlery	Poor economic conditions	Competitive environment	Cost of new technology
309	Miscellaneous Metal Fabricating	Poor economic conditions	Competitive environment/ Ability to finance	Lack of skills and know how to implement
315	Machinery and Equipment	Poor economic conditions	Ability to Finance	Competitive environment
318	Office and Store Machinery	Poor economic conditions	Ability to finance	Lack of skills and know how to implement
335	Communications Equipment	Poor economic conditions	Ability to finance	Lack of skills and know how to implement
321	Aircraft and Aircraft Parts	Poor economic conditions	Ability to finance	Cost of new technology

APPPENDIX 3 continued

		Impeding Factors, Ranked in Descending Order of Importance		
		First	Second	Third
165	Plastics Fabricating	Poor economic conditions	Cost of new technology	Ability to finance/ Lack of standardization
Services				
701	Chartered Banks	Cost of new technology	Poor economic conditions/ Lack of skills and know how	Lack of Government assistance
701	Trust Companies	Lack of skills and know how to implement	Ability to finance	Cost of new technology
721	Life Insurance	Cost of new technology	Lack of skills and know how to implement	Unwillingness to change
721	General Insurance	Cost of new technology	Lack of skills and know how to implement	Customer demands for changes
735	Insurance Brokers	Cost of new technology	Ability to finance	Poor economic conditions
909	Federal Government	Ability to finance	Lack of skills and know how to implement	Lack of new technology standardization
931	Provincial Government	Ability to finance	Lack of skills and know how to implement changes	Unwillingness to change

APPPENDIX 3 continued

		Impeding Factors, Ranked in Descending Order of Importance		
		First	Second	Third
Services continued				
951	Local Government	Ability to finance	Unwillingness to change	Lack of skills and know how to implement
544	Telephone Systems	Cost of new technology	Ability to finance	Lack of skills and know how to implement
545	Telegraph and Cable Systems	Poor economic conditions	Ability to finance	Competitive environment
631	Food Stores	Cost of new technology	Lack of skills and know how to implement	Lack of new technology
642	General Merchandise Stores	Cost of new technology	Lack of skills and know how to implement	Lack of new standardization
853	Computer Services	Ability to finance/ Lack of new technology	Lack of skills and know how to implement	Competitive environment/ Unwillingness to change
867	Management and Business	Ability to finance	Cost of new technology	Unwillingness to change/ Poor economic conditions

SOURCE: BOGGS, W. and R. White (Chairpersons); Report of the Ontario Task Force on Employment and New Technology. 1985, p. 111.

APPENDIX 4

TRAINING COSTS IN SELECTED INDUSTRIES, ONTARIO, 1981 TO 1995

		Training Costs as a Percentage of Labour Costs					Percentage of Training Costs Related to New Technology				
		Estimated			Expected		Estimated			Expected	
	Industry	1981	1984	1985	1990	1995	1981	1984	1985	1990	1995
	Manufacturing										
291	Iron and Steel	-	2.0	2.0	2.5	2.5	60	80	60	75	75
304	Metal Stamping, Pressing and Coating	-	2.0	1.5	2.0	2.0	15	20	25	30	30
306	Hardware, Tool and Cutlery	-	5.0	5.5	6.0	6.5	10	40	50	55	55
309	Miscellaneous Metal Fabricating	-	5.0	4.5	5.0	5.0	15	25	35	30	30
315	Machinery and Equipment	-	2.0	2.0	2.0	2.5	10	10	15	20	20
318	Office and Store Machinery	-	5.5	6.0	8.5	9.5	40	40	45	50	50
335	Communications Equipment	-	2.5	3.0	4.0	4.0	35	30	35	35	40
321	Aircraft and Aircraft Parts	-	4.0	6.0	7.0	7.5	50	55	60	65	65
165	Plastics Fabricating	-	3.0	5.5	6.0	6.0	25	40	45	55	55

Appendix 4 continued

		Training Costs as a Percentage of Labour Costs					Percentage of Training Costs Related to New Technology				
		Estimated			Expected		Estimated			Expected	
	Industry	1981	1984	1985	1990	1995	1981	1984	1985	1990	1995
	Services										
701	Charted Banks	2.0	2.5	2.5	2.0	2.0	25	20	30	40	40
701	Trust Companies	0.5	3.0	3.5	4.0	4.0	10	30	35	45	45
721	Life Insurance	4.5	5.0	5.5	7.0	7.0	40	60	60	60	65
721	General Insurance	2.5	3.0	4.0	4.5	5.0	25	25	40	45	40
735	Insurance Brokers	1.0	1.5	2.0	2.5	3.0	25	35	35	35	35
909	Federal Government	3.0	2.5	3.0	4.0	4.0	25	30	30	40	45
931	Provincial Government	1.5	1.5	2.0	1.5	1.5	30	35	40	50	50
951	Local Government	1.5	2.0	2.0	3.0	4.5	30	45	45	55	55
544	Telephone Systems	6.0	10.0	13.5	9.0	9.0	100	85	85	75	75
545	Telegraph and Cable Systems	-	-	-	-	-	-	-	-	-	-
631	Food Stores	1.0	1.0	1.0	1.5	1.5	20	20	20	35	35
642	General Merchandise Stores	-	-	-	-	-	-	-	-	-	-
853	Computer Services	3.0	11.5	12.5	10.0	10.0	35	55	55	55	55
867	Management and Business Consultants	3.0	4.0	4.0	4.0	4.0	30	45	50	45	45

SOURCE: BOGGS, W. and R. White (Chairpersons); Report of the Ontario Task Force on Employment and New Technology. 1985, p. 130.

APPENDIX 5

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